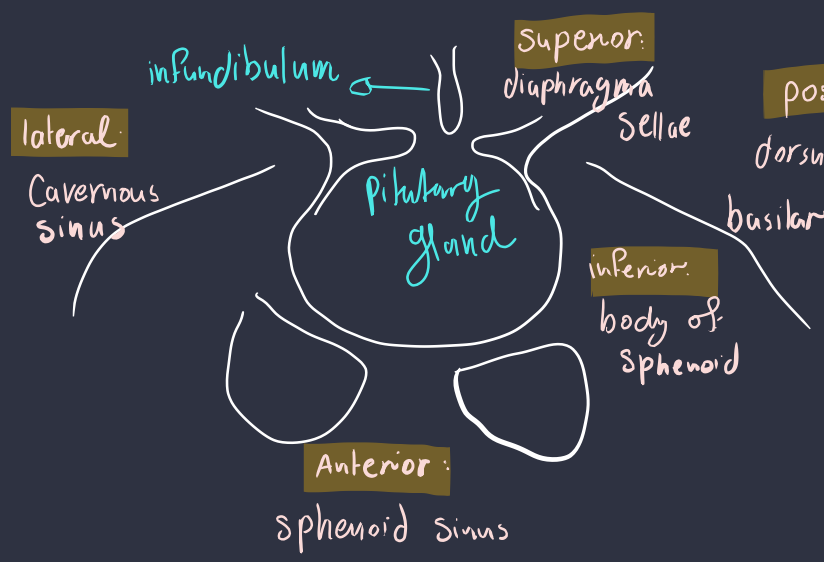
Pituitary gland: hypophysis cerebri

Trasnasal/Transsphenoidal
↓
to remove pituitary tumors

Relations:



BLOOD SUPPLAY

Superior hypophyseal artery (anterior lobe) ← from Cavernous Portion

Inferior hypophyse artery (Posterior lobe)

Internal carotid Artery

anterior / Posterior

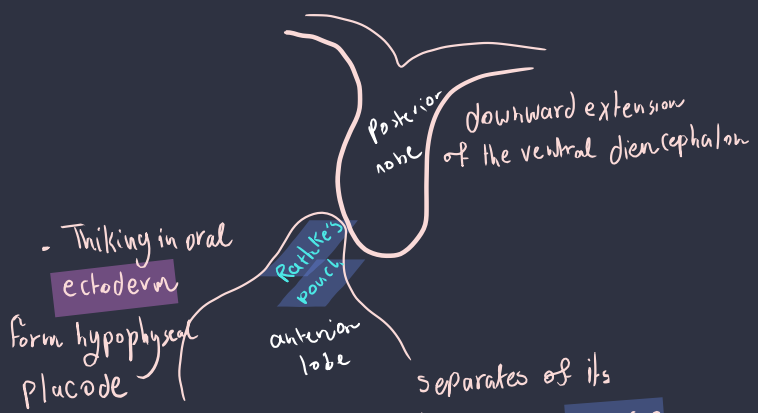
median eminence

CCA: from it / from CCA

Right: brachiocephalic

left: arch of the aorta

ORGANOGENESIS: during week 4



Acidophils → Secretory cells
Basophils → Chromophils: Stains + many vessels around
Chromophobes: X stains + less vessels

Portal Circulation

artery → primary plexus (capillary) → Portal vein → secondary plexus (capillaries)

releasing + inhibiting hormones

Hypothalamus:

- Supraoptic and Paraventricular nuclei are making 2 hormones: ADH and oxytocin

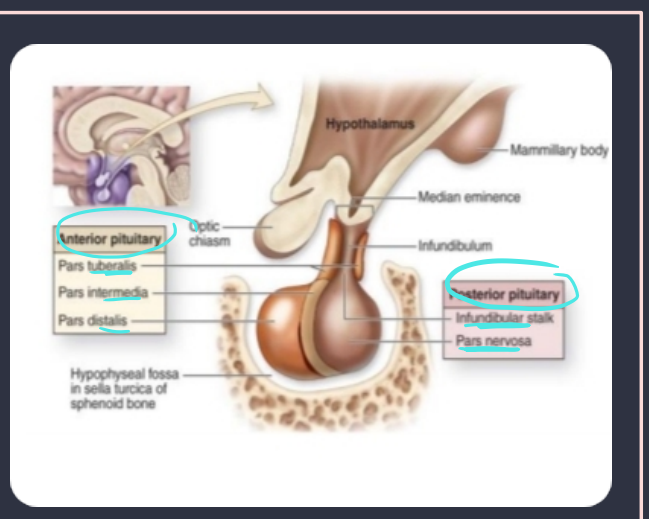
delived through the axons and stored in pars nervosa

2 structures of pituitary

Adenhypophysis anterior lobe

epithelial cells

- Pars distalis: Biggest, thin Capsule, Cords
- Pars tuberalis: surrounding the infundibulum
  - gonadotrophs are most of the cells
- Pars intermedia: between PD and PN
  - Contains:
- basophils (corticotrophs), Chromophobes and Colloid Filled Cyst
- active during fetal life
- unique function: Express POMC (MSH, γ-LPH and β-endorphin) → cleave it differently from cells in pars distalis

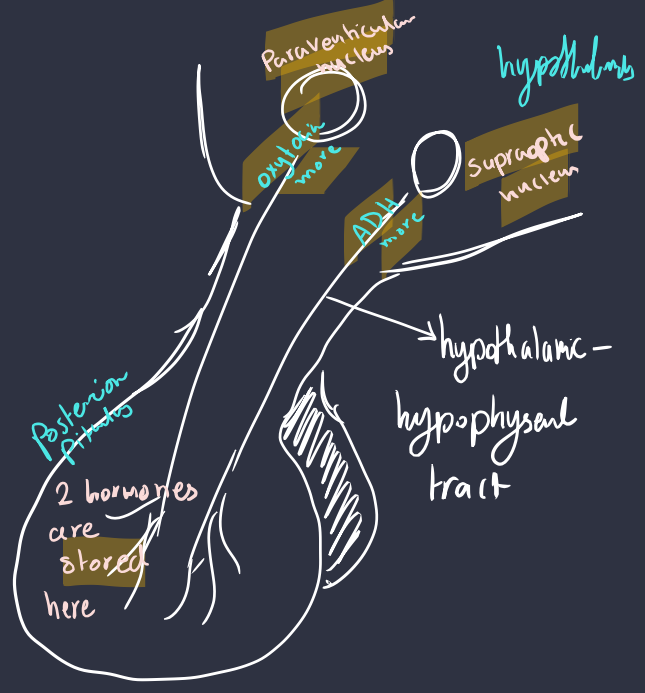


Neurohypophysis Posterior lobe

neural tissue

- Collection of unmyelinated axons
- Supporting cells called (Pituicytes) in pars nervosa

The Posterior pituitary:



- ADH and Oxytocin: cyclic peptide because of disulfide bond
- both have 9 amino acids, they only differ in 3 and 8.

1) **Oxytocin**: 3 → Ile // 8 → Leu
   - antidiuretic potency: 1 — Milk ejection → 100
   - Contraction of the pregnant uterus

2) **ADH // vasopression**: 3 → Phe // 8 → Arg
   - antidiuretic potency: 200 — Milk ejection → 1
   - Function → Regulate serum osmolarity: V_2 (↑ reabsorption of water in the renal tubules)
   - Function → vasoconstriction: V_1

* Stimulators:
- ↑ serum osmolarity
- ↓ ECF volume
- Stress-related factors
- Anti-neoplastic drugs

* Inhibitors:
- Ethanol
- β-Adrenergic Agonists
- ANP
- ↓ serum osmolarity

The anterior pituitary:

2 pathways:

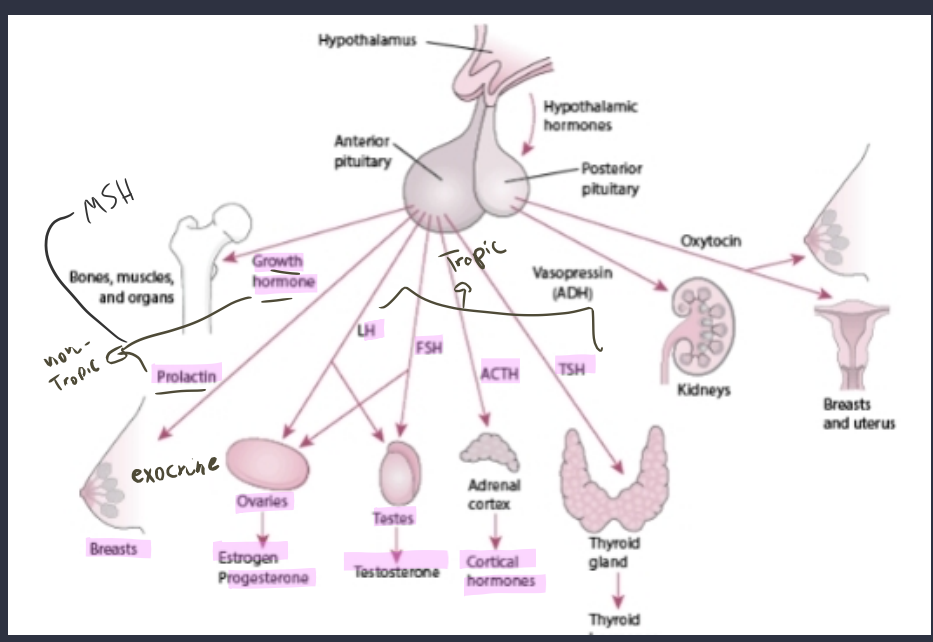
1) **Short pathway**: Hypothalamic-Hypophyseal short portal vessels (through posterior p)
2) **long pathway**: " " long portal vessels (through median eminence)

hypothalamus → nerve endings ~stimulation~ blood vessels of median eminence → anterior pituitary to stimulate it

Hypothalamic hormones that stimulate or inhibit A.P

- CRH → stimulate Corticotropes to release → ACTH 20%
- TRH → " Thyrotropes " " → TSH
- GnRH → " Gonadotropes " " → LH + FSH (least percentage)
- GHRH → " Somatotropes " " → GH 30-40%
- GHIH // Somatostatin → inhibit the release of GH
- PIH // Dopamin → inhibit prolactine hormone
  - only not peptide one

always stimulated
- lactotrops



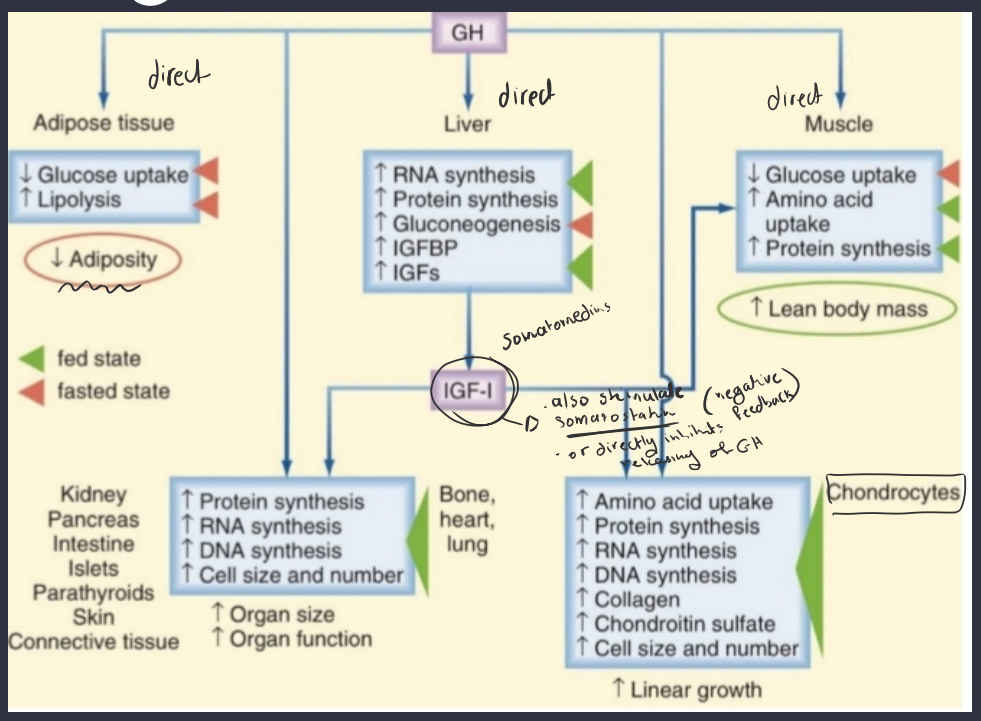
Growth hormone: 191 AA, single chain

- The major of growth in the normal Post-uterine life are GH and IGF-1

GH and insulin effect growth synergistically

- Many hormones stimulate growth synergistically:
  - ✓ insulin
  - ✓ Androgen
  - ✓ Thyroid hormone
  - ✓ Estrogen
  - ✓ Glucocoroid hormone (Cortisol)
  - ✓ IGF-1 (Somatomedin)

GH effects:



- So GH:
  - increase Protein synthesis
  - increase metabolism of fatty acid
  - decrease rate of glucose utilization (↑ glucose in the blood)
- GH causes diabetes → ↑ blood glucose → ↑ insulin secretion
- it can cause Ketogenic effect too,

- stimulate:
- ↓ blood glucose
- ↓ blood free fatty acid
- ↑ " amino acid
- Fasting · stress · exercise
- estrogen and testesterone
- Deep sleep (II & IV) · GHRH
- ghrelin

- inhibite:
- ↑ blood glucose
- ↑ " free fatty acid
- Aging · obesity
- somatostatin
- somatomedins
- GH exogenous

	GH	Somatomedin	insulin
protein intake	↑	↑	↑
Carbohydrate intake	↓	no effect	↑
Fasting	↑	↓	↓

Abnormalities:

1) Panhypopituitarism:
decrease secretion of all pituitary gland

2) severe anterior pituitary dificency:
decreace secretion of all anterior pituitary

3) moderate anterior pituitary dificency:
deficency in all anterior p except GH

4) Mild anterior pituitary dificency:
only Gonadotropins are defiect

- ADH dificency: diabetes insipidus
- oxytocin dificency: not Problematic
- Gonadotropins dificency:
  - Males: ↓ libido, Aspermia, ↓ body hair
  - Females: ↓ libido, Amenorrhea
  - Child: delayed puberty
- TSH dificency: hypothyradism
- ACTH dificency: ↓ glucocorticoids and androgens.
- GH dificency: cause dwarfism usually ✓ mentality, sometimes infertile
- GH oversecretion:
  - Gigantism: before adolescence
  - acromegaly: adults

DONE good job

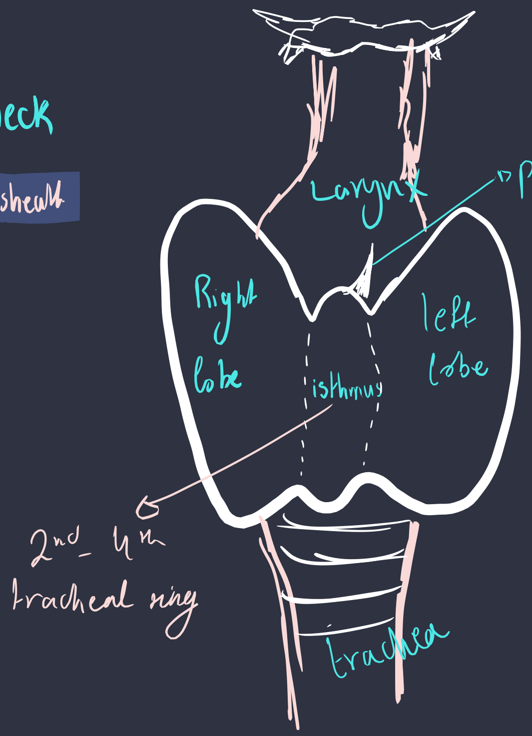
Thyroid Gland: The only gland that stores its hormones 3 months!

C5 - T1 ✓

. anterior neck

. surrounded by a sheath

attachment to larynx and trachea.



2 cartilage:
- thyroid cartilage
- cricoid cartilage

o relations of lobes:

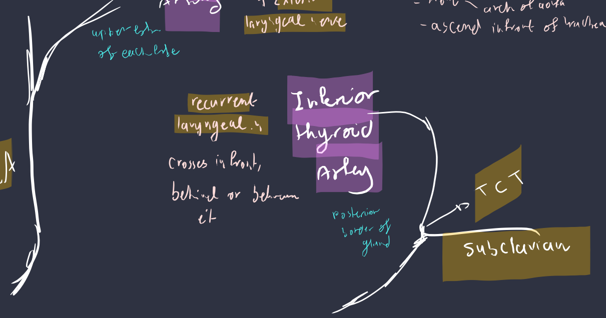
- medial: larynx, trachea, pharynx, esophagus, cricothyroid. m, external laryngeal. N, recurrent laryngeal. N
- . anterolateral: sternothyroid, sternohyoid, superior omohyoid, anterior sternocleidomastoid.
- . Posterolateral: Carotid sheath
- . Posterior: Parathyroid glands, anastomosis between superior and inferior thyroid artery

. Isthmus relations:

- Anterior: sternothyroid, sternohyoid, AJV, facia, skin
- superior: terminal. b of S. thyroid A
- Posterior: 2nd, 3rd, 4th ring of trachea

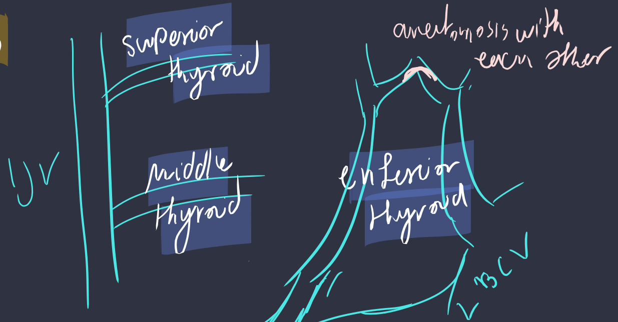
o BLOOD SUPPLAY

arteries:



Thyroidea ima: if present
- from < brachiocephalic / arch of aorta
- ascend infront of trachea

veins:



LYMPh D/ NERVE SUPPLY

. Lymph D: - laterally into deep cervical
- few to paratracheal

. Nerve supplay:
- Superior, middle, inferior cervical → sympathetic
- vagus nerve → parasympathetic

EMBRYOLOGY:

. originate from 1st + 2nd pouches (endoderm)

3rd _ 4th week:
Proliferate forming the thyroid diverticulum

5th week:
- . migrates along the midline, remains attached by thyroglossal duct
- . hollow then solidifies forming follicular element
- . division to right and left
- . ultimobranchial bodies from 4th/5th pouches → C-cells

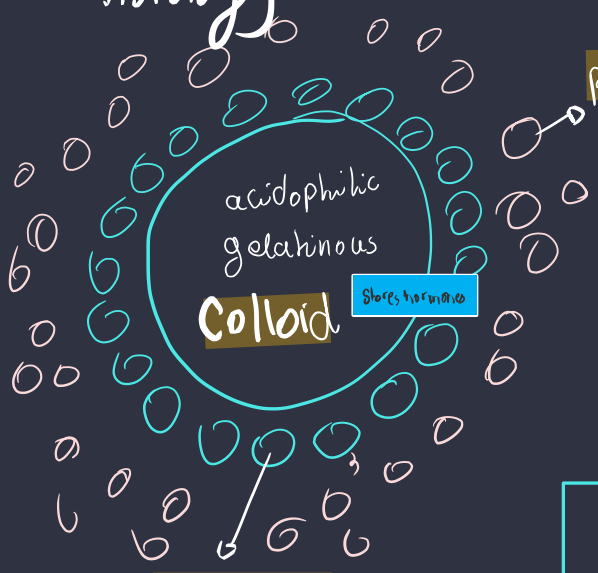
7th week:
final destination

10th week:
thyroglossal duct degenerates → incomplete?

1. thyroglossal duct cyst
2. lingual thyroid
3. Pyramidal lobe

11th week:
functionally mature

Histology



parafollicular cells (C-cells)
- larger, stain less
- ↓ RER / ↑ Golgi
- Secretion of Calcitonin → ↓ Ca^{2+}

Follicular cells (thyrocytes)
- densely packed together
- Squamous to columnar. Activity ↑ squamous
- round nucleus

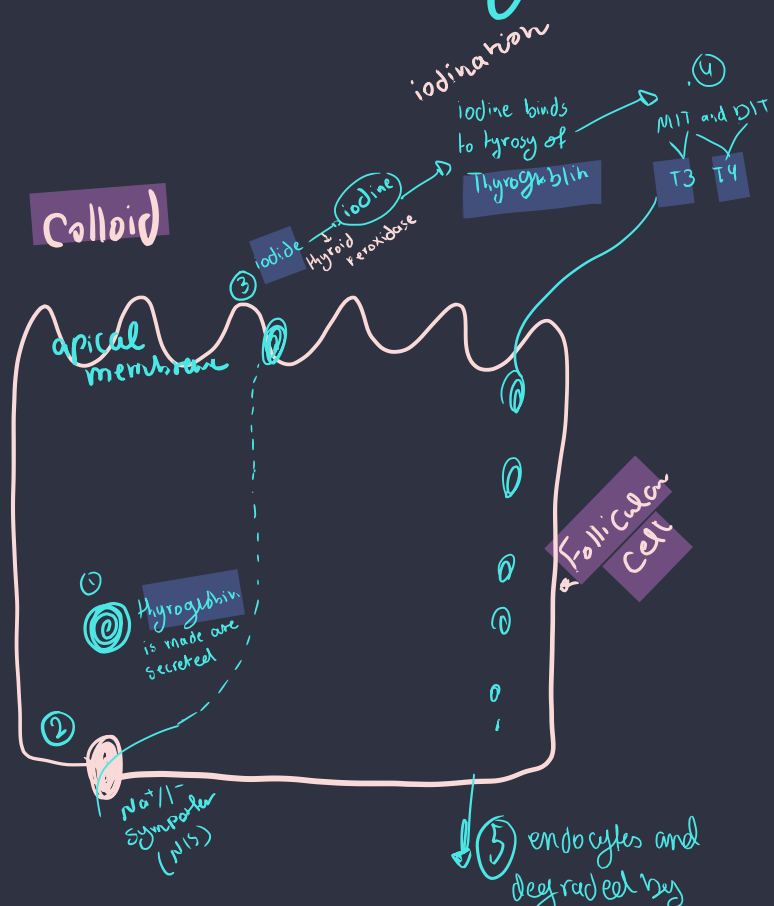
Synthesis the Thyroglobulin

- Thyroglobin immune-staining

99.5% bound — 99.98% bound
- T_3 is more active than T_4
- rT_3 is totally inactive
- T_4 is a prohormone

synthesis → 75% of T_3, 95% of rT_3

* production of thyroid H:

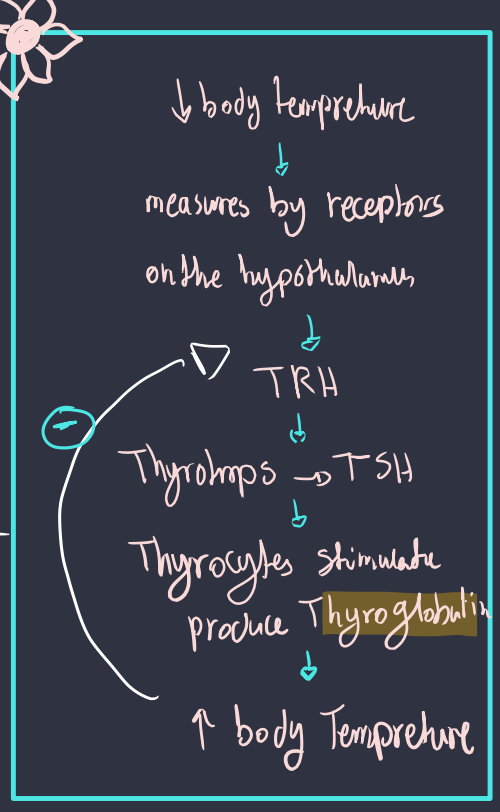


Free active T3 and T4

- Thyroid gland is stimulated by: TSH
- and inhibited by: Cortisol, GH, dopamine and somatostatin

TSH: Composed of
α + β subunit
- β: functional
- α: nonfunctional

- receptor in pituitary: phospholipase C
- receptor on the base of FC: adenylyl cyclase



• Thyroxin Transport:

- Circulate in the blood stream either bound to plasma Protein or free.
  - TBG
  - albumin
  - T_4-binding prealbumin

• Its Actions:

- Growth
- ↑ BMR
- Metabolism:
  - ↑ Glucose absorption
  - ↑ Lipolysis
  - ↑ protein synthesis
- maturation of CNS
- ↑ cardic output

Stimulatory Factors	Inhibitory Factors
TSH	I^- deficiency
Thyroid-stimulating immunoglobulins	Deiodinase deficiency
Increased TBG levels (e.g., pregnancy)	Excessive I^- intake (Wolff-Chaikoff effect)
	Perchlorate, thiocyanate (inhibit Na^+-I^- cotransport)
	Propylthiouracil (inhibits peroxidase enzyme)
	Decreased TBG levels (e.g., liver disease)

Thyroid hormone abnormalities:

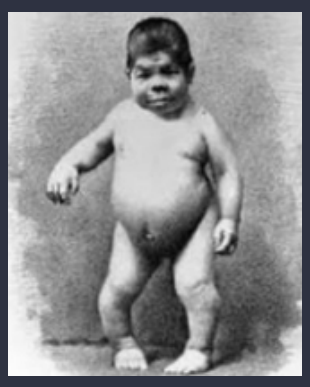
Hypothyroidism

- Fatigue and somnolence
- ↓ tissue oxidation and gut movement
- ↓ BMR, Heart and respiratory rate
- ↓ body temprehure, ↑ blood cholestrol, Slow voice, ↓ Apeptite, ↑ weight, dry hair

- A- Cretinism: during fetal life or childhood.

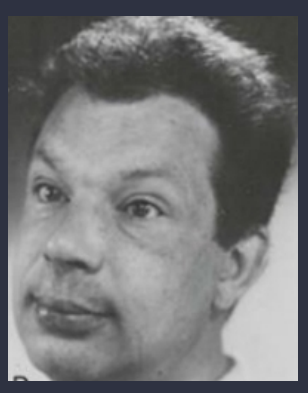
✓ mental retardation, ↓ body growth, ↓ sexual development

↳ Congenital
↳ endemic



B- Myxedema: in adults

- swelling of the face, beggginess under eyes



HyperThyroidism

- ↑ sweating
- muscle weakness
- nervousness or other psychic disorders
- extreme fatigue but inability to sleep
- Tremor of hands
- intolerance to heat

Causes are:

- Toxic goiter
- Graves disease:

A- exophthalmos: because of TSI

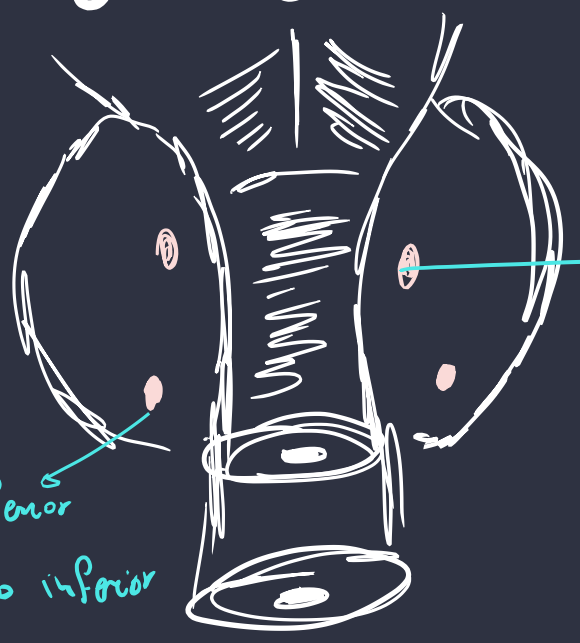
B- Goiter: occur in both hypo // hyperthyroidism

- Simple non-Toxic: low T_4, T_3
- Toxic, malignant: high T_4, T_3

DONE good job

Parathyroid gland:

The main controller of calcium level



- in the back of thyroid, usually embedded in the capsule.
- total 0.4 g
- Blood supp./Venous D/lymph D. same as thyroid

2 superior "more constant" (at the middle of posterior border of thyroid)

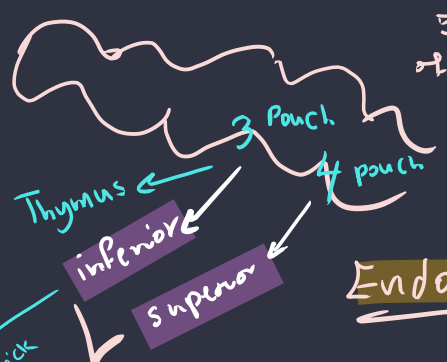
2 inferior (close to inferior poles)

*the older you get:-
- secretory cell → adipocytes

- location is more variable:
  - intra-thyrodial - within thymus
  - mediastinal structure - aortic arch

a single parathyroid gland should be sufficient!
↓
Removal of 3/4 causes transient hypoparathyroidism

EMBRYOLOGY:



STRUCTURE:

2 types of cells:
- Chief cells: Manage pTH
  - smaller, more abundant
  - prominent Golgi // developed ER
- oxyphil cells: - apper after puberty
  - large, increase in number with age.

Parathyroid hormone:

- it's a free protein 84AA

↓ Ca^{2+} in the blood → Calcium-sensening receptors detect this → start to secret PTH.

- dominant regulator is plasma Ca^{2+} level (11 mg/100 ml) ↓ → ↑PTH
- hypomagnesemia → ↑ PTH secretion
- ↑ plasma phosphate ind → ↑ PTH secretion
- ↑ $1,25(OH)_2$-D d → ↓PTH

- Its main function to control extracellular Ca^{+2} level by:

1) Renal Excretion (direct):

- increase $1,25\text{-}(OH)_2D_3$ formation → allow entery of both calcium and phosphat from the gut into the blood
  - → less phosphat reabsorption (decrease Plasma phosphate)
  - → more calcium reabsorption (increase Plasma Ca^{2+})

2) Bone Resorption (direct):

- PTH binds to receptors on osteoclast → release RANKL (OPGL) → binds to receptors on preosteolclast → mature osteoclasts develop a ruffled border → Enzymes, several acids → promote resorption of Ca^{+2} and phosphate

3) Inteshinal Absorphion (indirect)

via $1,25(OH)_2-D_3$ that facilitates the entry of eion through epithelium of the gut → increase Ca^{+2} absorphion and phosphate too → because $1,25(OH_2)-D_3$ only

*Parathyroid's underachivity:

- <7 mg/100mL → Tetany (because Ca^{+2} regulate Na^+ // $\downarrow Ca^{2+}$ = $\uparrow Na^+$ entery).
  - relieved by Calcium injechion / Large doses of Vit.D and PTH
- <5 mg/100mL → death occurs

Parathyroid's overachivity

- Great blood Ca^{2+} level → deposition of Calcium in unusual site (kidney) → Osteitis Fibrosa Cystica

. Vitamin D

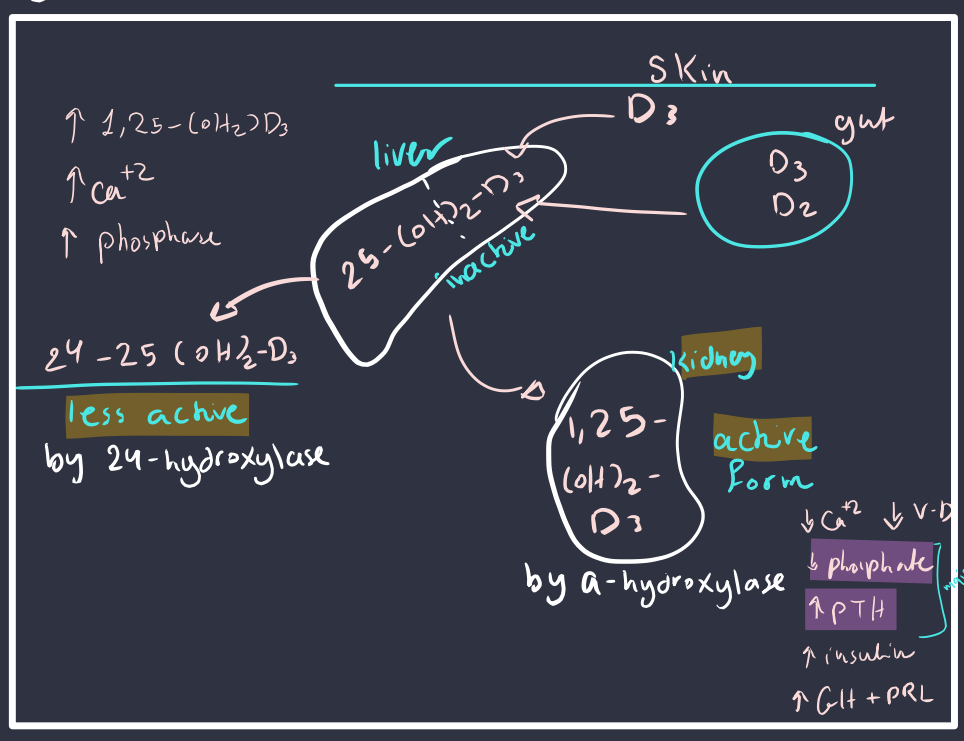
The second major regulatory for Ca^{+2} and phosphate metabolism

its roles → promote mineralization of new bone
- ↑ Ca^{+2} in plasma
- ↑ phosphate in Plasma

Vitamin D dihiency:

- needs several years to develop
- leads to failure of bone mineralization
  - osteomalacia
  - -rickets

obese people have type of fat captures vit.D → problems in bone and heart



Calcium Homeostasis

- PTH → ↑ Ca^{+2}
- Vit.D → ↑ Ca^{2+}
- Blood PH: → alkalosis: decrease free Ca^{2+} because they are bound to protein
  - → acidosis: increase free Ca^{2+} because it is replaced by H^+ in Protein

plasma calcium → Diffusible (effect secretion) → ionized
- → Non-diffusible → bound to albumin or globuin

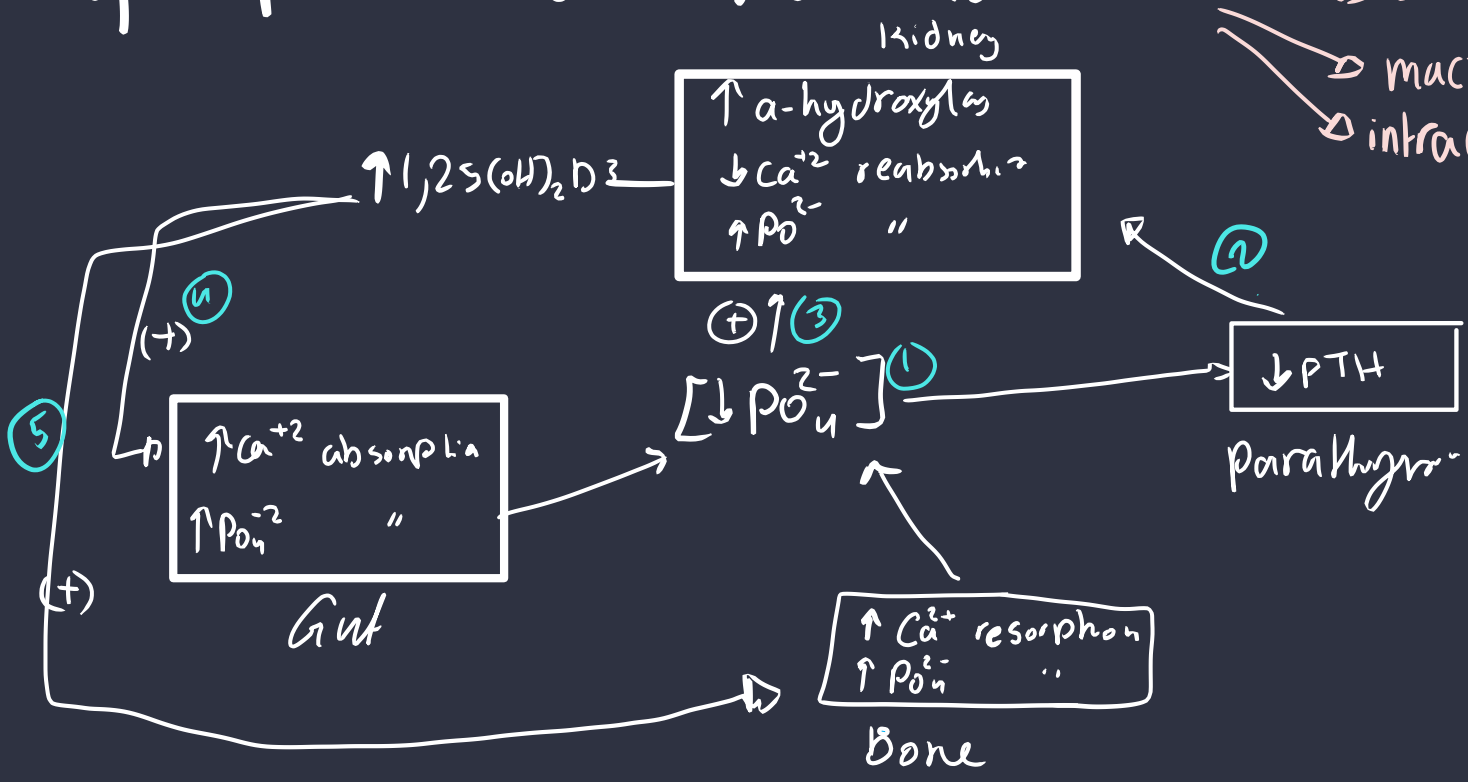
- Calcitonin: Secreted by thyroid Parafolliculer

on bone: decrease Ca^{2+} by antagonizing the achion of PTH and promoting Ca^{2+} deposihon into bones

on Kidney: decrease Ca^{2+} and Phosphate reabsorphion → ↑ both in urinery excrehion

•phosphate Function and Homeostasis

- constituent of bone
- macromolecules
- intracellular buffer system



Abnormalities of Ca^{+2} Homeostasis

1) Rickets: in children

- Lack of vitamin D → Calcium or phosphate deficiency
- in late spring months

2) osteomalacia: adult rickets

- Serious deficiency of Ca^{+2} and Vit.D → result of Steatorrhea

} cause bone disability

3) osteoporosis (decrease bone matrix)

- Problems in the metabolism of all bone constituents

Causes :

1. inactivity
3. ↓ vit. C
5. old age
2. Malnutrition
4. Postmenopausal
6. Cushing's syndrom and acromegly

• prevention :

1) Ca^{+2} intake and exercises
2) pharmacological → Anti-resorptive
   → stimulate bone formation
③ Biphosphate
④ estrogen
⑤ Vit.D

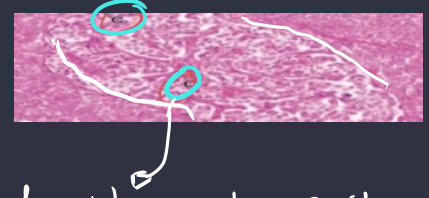
DONE ♥ good job

Pancreas

- mostly in the tail

- **Islets of Langerhans**: Compact or ovoid masses, more lightly stained than the surrounding acinar cells
  - endocrine cells embedded within the acinar exocrine tissue.
  - more than 1 M islets
  - a thin reticular capsule surrounds each islet
  - acidophilic or basophilic with fine cytoplasmic granules

Same embryonic origin as acinar → from endoderm of developing gut.



- several arterioles enter each islet's capillary → Peripheral → Central (before leaving)

CELLS:

1- α or A cells: secrete glucagon (proglucagon) and located peripherally

2- b or β cells: Secrete insulin and located Centrally (most numerous)
proinsulin / C peptide / Amylin

3- d or D cells: Secrete Somatostatin (scattered)

4- PP cells: (F cells) Secrete Polypeptide, Common in islets in head

5- Epsilon cells: Secrete Ghrelin

* Regulation of Glucose:

Short term

insulin + glucagon

long term

Catecholamines, GH, TH, Adrenal Corticosteroids

Glucagon: gluconeogenesis, glycogenolysis (1st)

Cortisol: gluconeogenesis, lypolysis (2nd)

Adrenalin: gluconeogenesis, glycogenolysis, lypolysis

GH: simalr to Cortisol

Stimulatory Factors	Inhibitory Factors
1) Increased glucose concentration 2) Increased amino acid concentration 3) Increased fatty acid and ketoacid 4) concentration 5) Glucagon 6) Cortisol 7)Glucose-dependent insulinotropic peptide (GIP) 8) Potassium 9) Vagal stimulation;acetylcholine 10) Sulfonylurea drugs (e.g.,tolbutamide, glyburide) 11) Obesity	1) Decreased blood glucose 2) Fasting 3) Exercise 4) Somatostatin α-Adrenergic agonists 5) Diazoxide

- The most important stimulatory of insulin is glucose:

↑ glucose → ↑ ATP → closed K^+ channels → opened Ca^{+2} channel → ↑ insulin

* Some notes about insulin:

like TSH

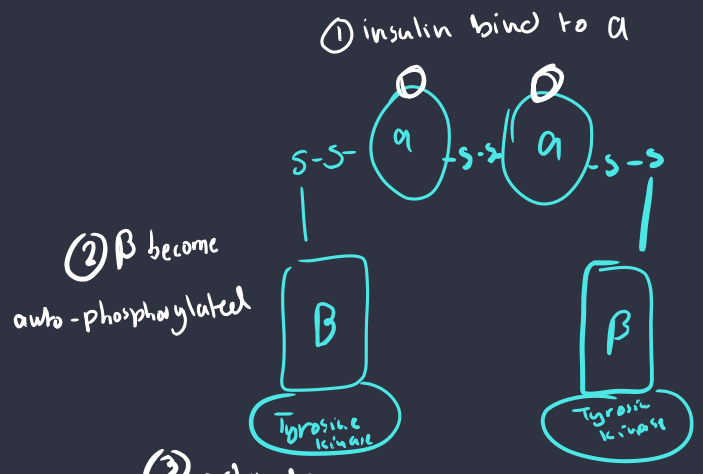
- 2 chains → A → 21AA
  → B → 30AA active
- disulfide bridges

help to measure endogenous insulin bc it's not extracted by liver

- pre-insulin (β cells) → pro-insulin (ER) → insulin + C peptide (Golgi)
- Insulin + C peptide are secreted with each other, small amount of Proinsulin.
  10% of insulin activity

½ 60 in liver

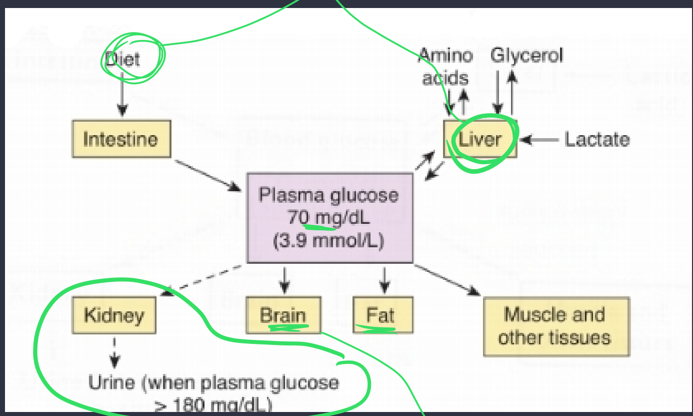
- insulin function:



④ insulin can do its effect

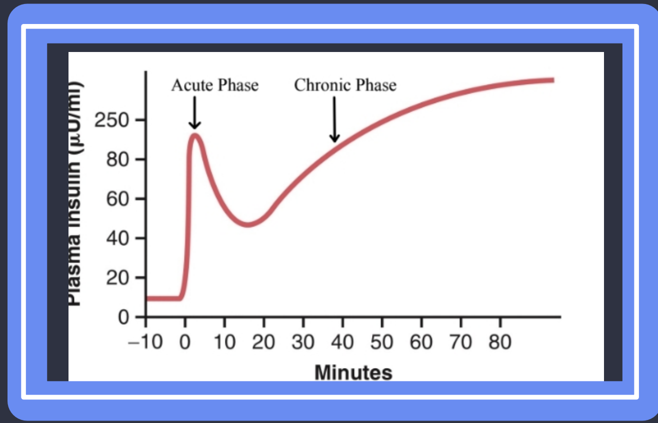
Glucose homeostasis:

Sources



- renal threshold (glycosuria)

→ glucose انتهي
brain عادي بتفوت
& insulin بس



sensing a rapid rise in Plasma glucose makes β cells secrete their stores of Presynthesized insulin **acute Phase** → secrete newly synthesized in **Chronic Phase**

Tissues in which insulin does not facilitate glucose uptake
Brain (except probably part of hypothalamus)
Kidney tubules
Intestinal mucosa
Red blood cells

Insulin Deficiency:

increase lypolysis

↓ insulin → ↑ enzyme hormone sensetive lipase → ↑ lypolysis → ↑ FFA in the blood (become the main engery substrate)

→ ↑ Ketone bodies

→ acidosis

Protein depletion

↓ insulin → ↑ Protein Catabolism

→ ↑ AA are dumped in Plasma

→ energy / gluconeogenesis

→ enhance urea

amino acids → Protein

wasting

Coma

- Acidosis + dehydration
- hyperosmolarity of Plasma
- lactic Acidosis

Diabetes mellitus

Feature	Type 1	Type 2
Age at onset	Usually <20 yr	Usually >40 yr
Body mass	Low (wasted) to normal	Visceral obesity
Plasma insulin	Low or absent	Normal to high initially
Plasma glucagon	High, can be suppressed	High, resistant to suppression
Plasma glucose	Increased	Increased
Insulin sensitivity	Normal	Reduced
Therapy	Insulin	Weight loss, thiazolidinediones, metformin, sulfonylureas, insulin

insulin secretogogues (sulfonylureas)

- biguanides (Liver)
- glitazones (peripheral)
- α - glucosidase inhibitors

- Glucagon: the most Potent hyperglycemic hormone

- The major stimulas of secretion → ingestion of protein
- The major target is the liver, but it act on other tissue

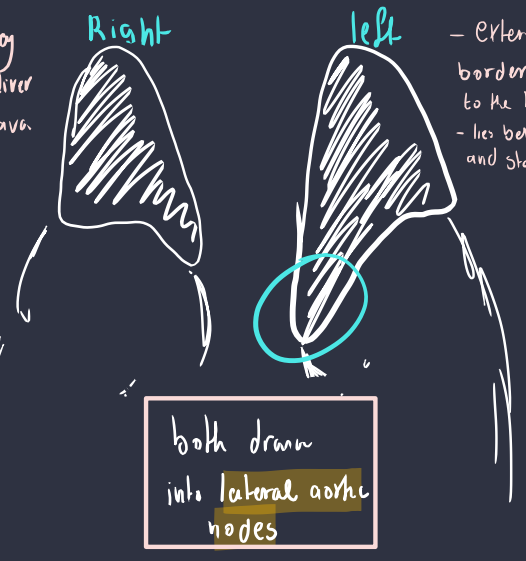
	Glucose	Insulin	Glucagon	Liver gives	Liver, fatm muscles cells take	Brain
At rest	Normal	Normal	Normal	10 g	4 g	6 g
During exercise	Normal	—	+	+ 46 g	+ 40 g	6 g Not affected
After a meal	+	++	–	— 0 g	+ 44 g	6 g Not affected

DONE ♡ good job

Adrenal Gland

- Surrounded by renal fascia
- lacks of hilum
- separated from kidney by perirenal fat

- Cap the right pole of kidney
- behind the right lobe of liver
- extend medially behind vena cava



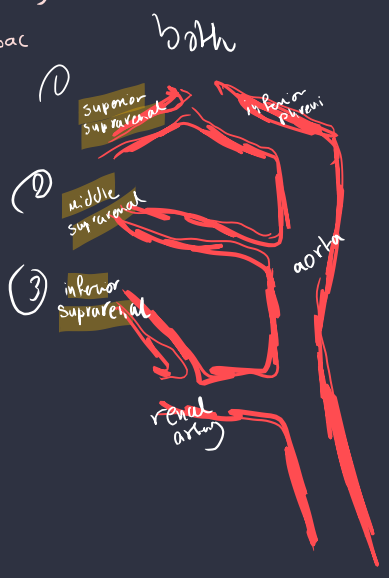
- extend along the medial border of the left pole of kidney to the hilus
- lies behind the pancreas, lesser sac and stomach

both are supplied by Preganglionic Sympathetic from splanchnic nerve

both drain into lateral aortic nodes

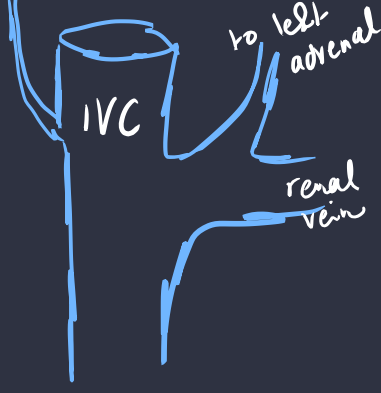
BLOOD SUPPLAY

both



to Right adrenal

to left adrenal



ORGANOGENESIS

Cortex
- 5th week → mesothelial cells → adrenal-gonadal primordial germ cells → fetal/primitive cortex
- Second wave of cell penetrate mesenchyme → definitive cortex
- After birth → outermost layer of fetal cortex → reticular zone

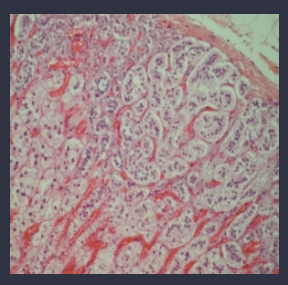
Medulla
- ectoderm
- originate in sympathetic system → invade middle aspect → arranged in cords → medulla
- stain yellow-brown (chromaffin)

Trauma → Adrenal gland is large in birth bc of fetal cortex, in the process of involution, the cortex is friable and susceptible to damage.

STRUCTURE

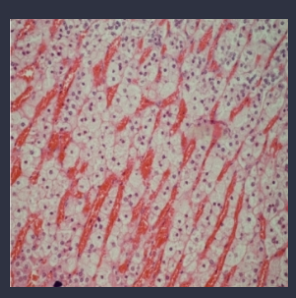
Adrenal cortex

- acidophilis - ↑ SER
- steroid, cholestrol - Steroide diffuse



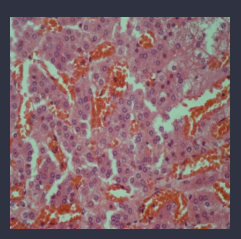
- ↑ capillaries
- ~15, Closely packed rounded or arched cords of columnar or pyramidal cells
- Mineralocorticoids (aldosterone)

zona Glomerulos



- 80% - long cords
- glucocorticoids (cortisol)
- ↑ lipid droplets
- controlled by ACTH
- small amount of androgen

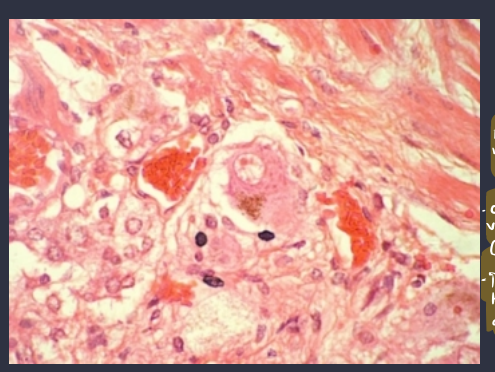
Zona Fasciculata



doesn't differentiate fully until 6-8 years from glomerulosa

- 10% - irregular cords
- heavily stained (↓ lipid)
- weak androgen (also cortisol)
- controlled by ACTH

Zona reticularis



- pale-staining
- CCs (modified sym post neurons)
- Catecholamines → epinephrine 80%, norepinephrine
  - ↑ rate, dilates bronchioles and arteries
  - constricts vessels of GIT and skin
  - ↑ blood flow to ♡, muscle and brain
- Conversion of epi → not only in Chromaffin cells

Adrenal medulla

- Adrenal cortical hormones
- Cholestrol is the pecursor. - X stored in gland
- Problem in last step of cortisol → ↑ Corticosterone + androgen

1-Glucocorticoids: (cortisol) major → Fasciculata minor → reticularis

Functions:
- production of glucose (gluconeogenesis) (Permissive effect with glucagon in glycogenolysis)
- Fat mobilization
- ↑ response to catecholamines
- Modulate CNS function
- during fetal life (type II cells of alveoli of the lung)

- Regulated by ACTH which stimulate Cholestrol desmolase

CRH ⊕ / ADH ⊕ → ACTH ⊕ → cortisol

- ✓ to aldosterone receptors, but hydroxysteroid dehydrogenase in Kidney inactivate it
  - 90% → bound to corticosteroid-BP
  - 6% → " to albumin
  - 4% → free (functional)

2-Mineralocorticoids (Aldosterone) zona glomerulosa (aldosterone synthase)

- increase Na^+ + water reabsorption → ↑BP and ↑excretion of K^+ + H^+

20 → CBP
40 → albumin
40 → free relatively high

RAS:
↓ renal blood flow → juxtaglomerular cells in Kidney convert Prorenin → renin → plasm renin Converte angiotensinogen → angiotensin I —(ACE in lung)→ angiotensin II → Stimulate aldosterone Secretion

direct:
1- Na^+-K^+ ATPase pump
2- Na^+-H^+ exchange
3- Na^+-bicarbonate Cotransport
} more potent in reabsorption of Na^+

indirect: Vasocontraction → ↑ colloid osmotic pressure + ↓ hydrostatic pressure → reabsorption of Na^+ and water

aldosterone-MR complex → membrane transporter protein and enzymes → Na^+ ↑ // K^+ and H^+ ↓

- Amiloride → X Na^+ reabsorption
- spironolactone → bind to MR protein

3-Androgens & Estrogen major zona reticularis minor zona Fasciculata

- 2 weak androgen are produced from:

dehydroepiandrosterone (DHEA) + Androstenedione → Testesterone

Testesterone → ① estradiol
Androstenedione → ② estrone
① estradiol or ③ estriol

1+2+3 = Estrogens

Female: pubic and axillary hair & libid
male: spermatogenesis, 2nd sex charc

DONE good job

PINEAL GLAND: epiphysis cerebri

- between the thalamic bodies
- Rich blood supplay
- postganglionic sympathetic nerve fibers
- covered by pia mater

CSF: produced by ependymal cells

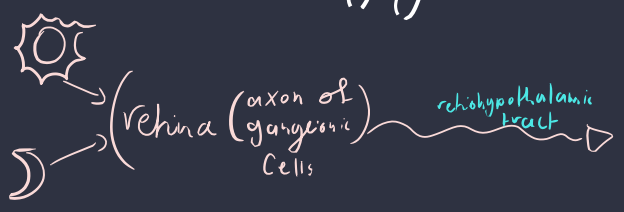
- Posteriorly from the posterior end of the roof of 3rd ventricle of the brain

- Histology: prominent secretory cells
  - slightly basophilic
  - many mitochondria / long cytoplasmic processes (modified nervous tissue)

- glial cell → enlonged nuclei, heavily stained
- Corpora arenacea → mineralization of Extracellular protein deposits

Melatonin: from tryptophan

↑ darkness, ↓ daylight



ORGANOGENESIS

- 7th-8th week
- from neuroectoderm
- The development of mature gland is seen in the first decade.

Functions

- influence activity of
  - PG
  - I.o.L of Pancreas
  - Parathyroids
  - adrenals
  - gonads
- inhibitory → directly (production)
  - indirectly (secretion)

DONE ♥ good job

11. Physiology

points to remember about endocrine system

1. single gland may produce multiple hormones 
2. Most hormones have multiple actions on the same tissue  (pleotropic)
3. some hormones have different effect in different target 
4. The same chemical massenger may be either a hormone or a neurotrasmitter
5. Multiplicity of regulation 
6. desensitization

Regulation of hormone secretion

- Feedback control
  - positive
  - negative
    - ultrashort-loop
    - short-loop
    - long-loop
- Neural Control
- Chronotropic Control
  - sleep awake
  - menstrual
  - seasonal
  - development

Regulation of receptors' number

- down-regulation (excess of hormone)
- up-regulation (increase in receptor's number)

interaction between hormones

- Permmissive hormonal interaction "effect requires previous exposure to another hormone"
- Synergistic effect "complement each other"
- Antagonistic effect "opposed by other"

Chemical classification of hormones

1. Protein

. hydrophilic

- one second messenger (adenylyl cyclase)

phosphodiesterase → cAMP

- 2 second messengers

phospholipase C ← IP_3, DAG

2. Amino acid

- lipophilic

• receptors inside the cytoplasm or inside the nucleus (thyroid hormones)

. Adrenaline → has different mechanism

3. Steroid

. Lipophilic

- same thyroid hormones
- Plasma membrane receptors

Progesterone + estradiol